HIGH-PERFORMANCE TYRE FOR A MOTOR VEHICLE

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The present invention relates to a high-performance tyre for a motor vehicle.

Description of the Related Art

In the present description and in the claims, the term "continuous track" denotes a portion of tread band of a tyre delimited continuously on only one of its sides, and the term "sipe" denotes a notch having a width of not more than 1 mm.

A first aspect of the invention consists in a high-performance tyre for a motor vehicle, provided with a tread having an overall width L and comprising two deep circumferential grooves which separate a central region from two lateral shoulder regions, said shoulder regions being provided with shoulder blocks, characterized in that the sum of the widths of said lateral shoulder regions is equal to or less than 60% of said overall width L, in that the width of each of said shoulder regions is not less than 20% of said overall width L, in that each of said circumferential grooves is adjacent, on the side further from said central region, to a continuous track from which transverse grooves branch to delimit said shoulder blocks.

~~Advantageously, said continuous track terminates in a continuous wall which forms a lateral wall of said circumferential groove.~~

~~Preferably, said continuous lateral wall of at least one circumferential groove has a profile, in a radial plane, which is more inclined, with respect to a centre-line axis of said circumferential groove, than the profile of the facing lateral wall of said circumferential groove.~~

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In one embodiment, said continuous lateral wall of said circumferential groove has an inclination in the range from approximately 14° to 24° with respect to said centre-line axis and a bottom radius R within a range from approximately 2 mm to 5 mm, while said facing lateral wall has an inclination in the range from

approximately 3° to 10° with respect to said centre-line axis and a bottom radius R1 in the range from approximately 4 mm to 7 mm.

Advantageously, said continuous lateral wall of said circumferential groove has an inclination of approximately 19° with respect to said centre-line axis and a bottom radius R of approximately 3.5 mm, while said facing lateral wall has an inclination of approximately 5° with respect to said centre-line axis and a bottom radius R1 of approximately 5 mm.

Preferably, at least one of said shoulder blocks has a sipe which is approximately transverse with respect to an equatorial plane.

Advantageously, said central region comprises at least a first and a second circumferential row of central blocks, delimited by one of said circumferential grooves and by another deep circumferential groove.

Preferably, said central blocks are of approximately rhomboid shape.

Advantageously, said central blocks are approximately cusp-shaped.

Preferably, said central region also comprises a third circumferential row of inner central blocks, adjacent to an annular projection, said third row of blocks and said projection being delimited by said other circumferential grooves.

Advantageously, said inner central blocks have an approximately semi-parabolic shape.

Preferably, said blocks of said central rows are separated by transverse grooves having a bottom wall with a shaped profile of variable depth.

A second aspect of the invention consists in a high-performance tyre for a motor vehicle, provided with a tread having a central region and two lateral shoulder regions, the central region being separated from each shoulder region by a deep circumferential groove, each shoulder region being provided with shoulder blocks separated by transverse grooves, characterized in that said shoulder blocks are joined at one

end by a continuous track which terminates in a continuous wall which forms a lateral wall of said circumferential groove.

A third aspect of the invention consists in a high-performance tyre for a motor vehicle, provided with a tread having a central region and two lateral shoulder regions, the central region being separated from each shoulder region by a deep circumferential groove, each shoulder region being provided with shoulder blocks separated by transverse grooves, characterized in that said shoulder blocks are joined at one end by a continuous track which terminates in a continuous wall which forms a lateral wall of said circumferential groove, said continuous wall of at least one circumferential groove having a profile in a radial plane which is more inclined, with respect to a centre-line axis of said circumferential groove, than the profile of the facing lateral wall of said circumferential groove.

A fourth aspect of the invention consists in a method for promoting a uniform distribution of a tread compound of a tyre during vulcanization in a suitable mould, comprising the step of shaping profiles of bottom walls of transverse grooves of said tread with a variable depth to facilitate the longitudinal migration of said compound along the pitch sequence of said tread.

The tyre according to the invention provides high performance, both when it is new and when it is partially worn. This high performance consists primarily in a high plastic and acoustic travelling comfort and a high resistance to aquaplaning, both in straight travel and when cornering, together with good handling properties on dry and wet ground.

In particular, the presence of a continuous track which joins the shoulder blocks reduces the appearance of the typical irregular and premature deformations known as "saw tooth" wear phenomenon on the edges of the transverse grooves and of the adjacent circumferential

groove during the rolling of the tyre, and thus improves its mileage yield.

SubA5 In a further aspect, the invention relates to methods and tyres which make it possible to control certain design characteristics of a tyre, such as the possibility of optimizing the flow and consequent distribution of the tread compound along the crown of the tyre.

SubA6 In a further aspect, the invention relates to methods and tyres which make it possible to control certain behaviour characteristics of a tyre, particularly a high-performance tyre, such as the possibility of controlling the wear degree and rate of the tread band in use, as well as the roadholding in both dry and wet conditions, the plastic comfort and/or quietness of running in severe conditions of use at high running speeds.

BRIEF DESCRIPTION OF THE DRAWINGS

Further characteristics and advantages of the invention will now be illustrated with references to embodiments illustrated by way of example and without restriction in the attached figures, in which

Fig. 1 is a perspective view of a tyre according to the invention;

Fig. 2 is a partial plan view of a tread of the tyre shown in Fig. 1;

Fig. 3 is a view in partial section, in a radial plane, of the tyre shown in Fig. 1;

Fig. 4 is a perspective view of another tyre according to the invention;

Fig. 5 is a partial plan view of a tread of the tyre shown in Fig. 4;

Fig. 6 is a view in partial section, in a radial plane, of the tyre shown in Fig. 4;

Figs. 7 and 8 are diagrams which show the variation of the noise level as a function of speed, measured in a vehicle fitted with tyres according to the invention and with conventional tyres;

Fig. 9 shows the profile of blocks of a tread of a tyre according to the invention along an axial sequence of meridian planes, reconstructed by a laser beam after a certain period of use.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 shows a high-performance tyre 1 for a motor vehicle. Tyre 1 is of the asymmetric type; in other words, it has a pattern which is different (i.e. asymmetric) on each side of an equatorial plane 10 (Fig. 2).

The structure of the tyre is of the conventional type and comprises a carcass, a tread band located on the crown of said carcass, a pair of axially superimposed sidewalls terminating in beads reinforced with bead wires and corresponding bead fillers, for securing said tyre to a corresponding mounting rim. The tyre preferably also comprises a belt structure interposed between the carcass and the tread band. More preferably, the tyre of the of the type with a markedly flattened section, for example in the range from 0.65 to 0.30, where these figures express the percentage value of the ratio between the height of the cross right section of the tyre and the maximum chord of said section. In the art this ratio is usually referred to as H/C.

The carcass is reinforced with one or more carcass plies fixed to said bead wires, while the belt structure comprises two belt strips, formed from lengths of rubberized fabric incorporating metal cords, parallel to each other in each strip and crossing over those of the adjacent strips, preferably inclined symmetrically with respect to the equatorial plane, and radially superimposed on each other. Preferably, the carcass also comprises a third belt strip, in a radially outermost position, provided with cords, preferably textile and even more preferably made from heat-shrinkable material, orientated circumferentially, i.e. at zero degrees with respect to said equatorial plane.

Tyre 1 has a tread 2 made from a predetermined compound, provided with deep circumferential grooves 3, 4, 5 and 6. Grooves 3 and 6 divide a central region 7 of the tread from two shoulder regions 8 and 9, located respectively on the left and on the right of equatorial plane 10.

Central region 7 comprises three circumferential rows of blocks 11, 12 and 13. Shoulder region 8 comprises a circumferential row of blocks 14 and shoulder region 9 comprises a circumferential row of blocks 15.

The row of blocks 14 comprises shoulder blocks 20, of approximately rectangular shape, separated from each other by transverse grooves 21. Each block 20 has a sipe 23 which is approximately transverse with respect to equatorial plane 10 and is aligned with a transverse recess 24 towards the outer edge of the tread. Blocks 20 are joined at one end by a continuous annular track 22 which terminates in a continuous wall 103 which forms a lateral wall of groove 3.

The row of blocks 11 is delimited by circumferential grooves 3 and 4. Row 11 comprises outer central blocks 26 of an approximately rhomboid shape, separated from each other by transverse grooves 27. Blocks 26 are divided into three portions 26a, 26b and 26c. The two portions 26a and 26b are separated by an approximately transverse sipe 28, are axially adjacent to third portion 26c and are separated from the latter by a circumferential recess 29. Blocks 26 terminate in walls 30 which form a notched lateral wall 203 of groove 3.

For example, groove 3 has a width of approximately 10.5 mm and a depth of approximately 8 mm and its lateral walls 103 and 203 are inclined at approximately 5° with respect to a centre-line axis, and are joined by a bottom radius of approximately 4.5 mm.

The row of blocks 12 is delimited on one side by circumferential groove 4 and is adjacent, on the opposite side, to an annular projection

35, which in turn is delimited by circumferential groove 5. Row 12 comprises inner central blocks 36 of approximately semi-parabolic shape, separated from each other by approximately transverse grooves 37, and separated from projection 35 by a circumferential groove 38 which has a half-wave harmonic course.

The row of blocks 13 is delimited by circumferential groove 6 and is adjacent to an annular projection 40, which, in turn, is delimited by annular groove 5. Row 13 comprises outer central blocks 41 of approximately rhomboid shape, separated from each other by transverse grooves 42. Each block 41 is separated from projection 40 by a circumferential recess 43. Blocks 41 terminate in walls 44 which form a notched lateral wall 206 of groove 6.

The row of blocks 15 comprises shoulder blocks 120, of approximately rectangular shape, separated from each other by transverse grooves 121. Each block 120 has an approximately transverse sipe 123, aligned with a transverse recess 124 towards the outer edge of the tread. Blocks 120 are joined at one end by a continuous annular track 122 which terminates in a continuous wall 106 which forms a lateral wall of groove 6.

Preferably the two shoulder regions have different widths from each other; for example, the narrower shoulder 8 (on the vehicle side) has a width of approximately 25% of the total width of the tread, while the wider shoulder 9 (preferably on the outer side) has a width of approximately 28% of the total width of the tread.

Continuous lateral wall 106 of groove 6 has a profile, in the radial plane (Fig. 3), which is more inclined with respect to a centre-line axis of the groove, in other words which is more bulky, than the profile of facing lateral wall 206. For example, groove 6 has a width of approximately 10.5 mm and a depth of approximately 8 mm, and wall 106 has an inclination of approximately 19° with respect to its centre-

line axis and a bottom radius R of approximately 3.5 mm, while wall 206 has an inclination of approximately 5° with respect to the centre-line axis and a bottom radius R1 of approximately 5 mm.

The presence of continuous track 122 imparts optimal rolling to tyre 1, since it prevents the formation, as a result of wear, of "saw tooth" wear deformations on the edges of transverse grooves 121 and of sipes 123, which would give rise to noise and discomfort in travel.

The particular shape of groove 106, located on the outer edge of the tread, i.e. on the side which is on the exterior of the vehicle when fitted, also makes it possible to improve the wear-resistance of the shoulder of the tyre during severe use in cornering (at high speeds and radii), thus significantly reducing premature wear, particularly of the "saw tooth" wear phenomenon type, on the edges of the circumferential groove. This minimizes the usual degradation of the performance of the tyre due to wear.

Transverse grooves 27 of the row of blocks 11 have a bottom wall 127 (Fig. 3) which has a cambered profile in a radial plane.

Preferably, this profile is of the curvilinear type and extends approximately along an arc whose shape is chosen in such a way as to promote the migration of the compound according, for example, to the viscosity of said compound, which is preferably in the range from 40 ML(1+4) to 110 ML(1+4) (Mooney viscosity), according to information which will be familiar to those skilled in the art. Preferably, this curvilinear profile has a radius of curvature in the range from 25 to 110 mm.

Transverse grooves 37 of the row of blocks 12 have a bottom wall 137 with an inclined profile decreasing towards circumferential groove 4. Preferably, this inclined profile has a moderately curvilinear form with a radius of curvature in the range from 90 to 120 mm.

Also transverse grooves 42 of the row of blocks 13 have a bottom wall 142 with an inclined profile decreasing towards groove 6. Preferably, said inclined profile has a moderately curvilinear form with a radius of curvature in the range from 90 to 120 mm.

This configuration with variable depths of the profiles of bottom walls 127, 137 and 142 of transverse grooves 27, 37 and 42 promotes a uniform distribution of the tread compound during vulcanization in an suitable mould, since it facilitates the longitudinal migration of said tread compound along the pitch sequence of the pattern. In this way, non-homogenous and unbalanced distributions of the masses are prevented.

For example, in a 225/40 ZR 18 tyre, tread 2 has a width L of approximately 243 mm, shoulder region 8 has a width of approximately 61.5 mm, and shoulder region 9 has a width of approximately 67.5 mm.

Each block 120 of row 15 is produced by rotating of 180° a block 20 of row 14 about an axis lying in the plane of the sheet and passing through equatorial plane 10. The block thus produced is then turned over through 180° with respect to an axis lying in the plane of the sheet and perpendicular to equatorial plane 10.

The pattern of tread 2 has four different pitch values distributed along the extension of the tread according to a predetermined pitch sequence. Each pitch represents the length, in a predetermined circumferential direction, of one block and of the adjacent transverse groove; for example, a block 20 or 120 and adjacent groove 21 or 121. The pitch sequence is produced according to the invention of US Patent 5,371,685, in order to modulate the noise emitted by the tyre and, in particular, to avoid a siren effect (the presence of resonant phenomena, particularly at high frequency).

Fig. 4 shows a high-performance tyre 51 for a motor vehicle. Tyre 51 is of the directional type; in other words it has a pattern which is symmetrical about an equatorial plane 50 (Fig. 5).

Tyre 51 has a tread 52 made from a predetermined compound, provided with deep circumferential grooves 53, 54, 55 and 56. Grooves 53 and 56 divide a central region 57 of the tread from two shoulder regions 58 and 59, located respectively on the left and on the right of equatorial plane 50. Circumferential grooves 54 and 55 have a half-wave harmonic course.

Central region 57 comprises two circumferential rows of blocks 60 and 61. Shoulder region 58 has a circumferential row of blocks 62 and shoulder region 59 has a circumferential row of blocks 63.

The row of blocks 62 comprises shoulder blocks 64, of approximately rectangular shape, separated from each other by transverse grooves 65. Each block 64 has an approximately transverse sipe 68 aligned with a transverse recess 69 towards the outer edge. Blocks 64 are joined at one end by a continuous annular track 66 which terminates in a continuous wall 153 which forms a lateral wall of groove 53.

The row of blocks 60 is delimited by circumferential grooves 53 and 54, and comprises central blocks 70 which are approximately cusp-shaped. Blocks 70 are separated from each other by approximately transverse grooves 71 and are divided into two portions 70a and 70b by a curved notch 72. Portion 70a has an approximately transverse sipe 73. Blocks 70 terminate in walls 74 which form a notched wall 253 of groove 53. Transverse grooves 71 have a bottom wall 271 with an inclined profile decreasing towards circumferential groove 53.

Continuous lateral wall 153 of groove 53 has a profile in a radial plane which is more inclined with respect to a centre-line axis of the groove, in other words which is more bulky, than the profile of facing

lateral wall 253. For example, groove 53 has a width of approximately 12 mm and a depth of approximately 8 mm, and the wall 153 has an inclination of approximately 14° with respect to a centre-line axis and a bottom radius R of approximately 4.5 mm, while wall 253 has an inclination of approximately 5° with respect to the centre-line axis.

Central region 57 also comprises two annular projections 75 and 76 located on the left and on the right of equatorial plane 50. Projection 75 is delimited by half-wave annular groove 54 and by a circumferential recess 77. Projection 76 is delimited by circumferential recess 77 and by half-wave annular groove 55.

The row of blocks 61 is delimited by circumferential grooves 55 and 56, and comprises central blocks 170 which are mirror images of and out of alignment with blocks 70. Blocks 170 are separated from each other by transverse grooves 171 and are divided into two portions 170a and 170b by a thin curved notch 172. Portion 170a has an approximately transverse sipe 173. Blocks 170 terminate in walls 174 which form a notched wall 256 of groove 56. Transverse grooves 171 have a bottom wall 371 with an inclined profile decreasing towards circumferential groove 56.

The row of blocks 63 comprises shoulder blocks 164 which are mirror images of and out of alignment with blocks 64. Shoulder blocks 164 are of approximately rectangular shape and are separated from each other by transverse grooves 165. Each block 164 has an approximately transverse sipe 168 aligned with a transverse recess 169 towards the outer edge. Blocks 164 are joined at one end by a continuous annular track 166 which terminates in a continuous wall 156 which forms a lateral wall of groove 56.

Continuous lateral wall 156 of groove 56 has the same profile (identical and a mirror image) and the same dimensions as continuous lateral wall 153 of groove 53.

For example, in a 225/40 ZR 18 tyre, tread 52 has a width L of approximately 237 mm and shoulder regions 58 and 59 have each a width of approximately 73 mm.

Specimens of tyres 1 and 51 were made and were shown to have excellent performance (comfort, quietness, resistance to aquaplaning and to wear) by tests of comparison with conventional tyres conducted both in the laboratory (indoor tests) and on the road and track.

The tyres according to the invention were compared with the PZero tyre made by the Applicant, which at present is considered to be the reference standard by motor vehicle manufacturers, and with equivalent tyres which represent commercially available alternative types of both asymmetric and directional tyres. Furthermore, the tyre of the present invention has been compared with two commercial tyres selected among the most sold ones. The first was an asymmetric tyre referred to hereinafter as C_1 and the second was a directional tyre referred to hereinafter as C_2.

The vehicle used for the tests was a Porsche Carrera 996 fitted, depending on the type of test to be conducted, with four asymmetric tyres or, alternatively, with directional tyres on the front wheels and asymmetric tyres on the rear wheels. The tyres fitted on the front wheels were of the 225/40 ZR 18 type, and those fitted on the rear wheels were of the 265/35 ZR 18 type.

The tyres were fitted on standard rims and were inflated to the nominal operating pressure.

- Comfort test with totally asymmetric fitting.

Given that the used assessment scale ran from -3 to +3 and represented a subjective judgement expressed by the test driver who tested and compared in sequence all the fittings on a route that was mixed in terms of the type of road layout (motorway, ordinary road,

straight, twisting), the road surface (smooth, rough) and the speed of travel, the results were as follows:

	Invention	PZero	C_1
Plastic comfort	1.2	1.2	0.6
Acoustic comfort	1	0.6	1

In this type of test, plastic comfort was evaluated according to the set of sensations perceived by the test driver with respect to the tyre's capacity for absorbing rough areas of the road surface.

Also, in this type of test, "acoustic comfort" denotes the noise perceived by the test driver inside the passenger compartment.

- Obstacle test.

The test consisted in making the tyre, loaded with the nominal operating load, to rotate against a road wheel mounted with a vertical axis of rotation and rotating at a speed in the range from 150 km/h to 0 km/h. The road wheel carries on its radially outer surface a bar of parallelepipedal shape of predetermined dimensions which forms the obstacle. The tyre is fitted on a fixed dynamometer hub which measures the excitation (force at the hub) that the obstacle produces on the tyre.

The test yielded the three-dimensional diagrams of the amplitude of the force as a function of speed and frequency. Areas which could be characterized by ranges of speed and frequency were selected from these diagrams and the root mean square value of amplitude (expressed in kg) which forms a parameter predicting the plastic comfort characteristics of the tyre was calculated for each of these areas.

a) Asymmetric tyre

Root mean square value	Invention	C_1
Radial	45	48
Longitudinal	53	62

b) Directional tyre

Root mean square value	Invention	C_2
Radial	44	50
Longitudinal	51	61

The range of measurement of the root mean square value in the radial direction of the tyre was from 20 Hz to 40 Hz with a speed decreasing from 120 km/h to 10 km/h.

The range of measurement of the root mean square value in the longitudinal direction of the tyre was from 60 Hz to 140 Hz with a speed decreasing from 120 km/h to 10 km/h.

In the obstacle test, the assessment expressed by the test driver in the evaluation of the plastic comfort improved as the root mean square value, such as that of the tyres according to the invention, decreased.

- Straight-line aquaplaning test.

The test was conducted on a straight section of smooth asphalt of predetermined length with a film of water of predetermined constant depth which was automatically restored whenever the test vehicle passed through it. In a first step, the speed (km/h) at which the tyres started to lose adhesion was measured (V1); in a second step, the speed (km/h) at which there was total loss of adhesion was measured (V2).

a) Asymmetric tyre

	Invention	PZero	C_1
V1	86.5	83	86
V2	90.5	87	90.5

b) Directional tyre

	Invention	C_2
V1	87	87.5
V2	92.5	91

- Cornering aquaplaning test.

The test was conducted on a section of route with smooth and dry asphalt on a bend of constant radius having a predetermined length and having, in a final section, an area of predetermined length covered with a film of water of predetermined thickness.

During the test, the maximum centrifugal acceleration and the maximum speed of the vehicle corresponding to complete aquaplaning were measured. The table shows the values of acceleration and speed expressed as a percentage, the value for the reference tyre (PZero) being set at 100 in each case.

a) Asymmetric tyre

	Invention	PZero	C_1
Max. acceleration	109	100	113
Max. speed	106	100	105

b) Directional tyre

	Invention	PZero	C_2
Max. acceleration	122	100	111
Max. speed	110	100	106

- Noise test.

Tests were conducted in a chamber acoustically insulated from the exterior (semi-anechoic chamber) with a Porsche car, as specified above, fitted first with new tyres according to the invention and then with new commercial comparison tyres.

Figures 7 and 8 show the graphs of noise inside the vehicle (dB(A)) as a function of the decreasing speed from 180 to 20 km/h, for a front left-hand tyre and a rear left-hand tyre respectively. More particularly, the curve A relates to the commercial comparison tyre and the curve B relates to the tyre according to the invention.

Noise tests on the road were carried out on the same vehicle fitted with the aforesaid new tyres, and the results were expressed according to the subjective evaluation of the test driver. The evaluation of the

tyres according to the invention and the commercial comparison ones was 7, where the limit of acceptability of new tyres is 6.

The noise test on the road was repeated, only for the vehicle fitted with the tyres according to the invention, at successive mileage intervals, with the following results:

- after 3,240 km, the noise level was 6.5;
- after 6,840 km, the noise level was 6;
- after 10,800 km, the noise level was 6.

At this point the tyres were returned to the semi-anechoic chamber, where the noise values shown by curves C of Figs. 7 and 8 were measured.

The data confirm that the tyre according to the invention, in spite of degradation, maintains a noise level equal to the threshold of acceptability of new tyres, even after 10,800 km of use.

During this period of use, it was also found that the wear, particularly on the shoulders, was considerably reduced: the tyre was found to be practically free of signs of premature and uneven wear, specifically of the "saw tooth" wear phenomenon type.

In particular, the measurements of tread wear were carried out at the same time as the noise tests and the results are shown in the attached graphs (Fig. 9) which represent the profile of the blocks, along an axial sequence of meridian planes, reconstructed by a laser beam. The measurements shown in Fig. 9 were made after 10,800 km of use of the 225/40 ZR 18 tyre. The first two profiles relate to the blocks of the right-hand shoulder, the profiles of the third to the sixth relate to the blocks of the central rows, and the last two profiles relate to the blocks of the left-hand shoulder.

Each graph shows a portion of the circumferential extension of the tyre where it will be noted that the decrease of the height of the blocks

due to wear takes place in a practically uniform way on the periphery of each block and in all of the blocks.